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SHOCK-TUBE THERMAL CONDUCTIVITY

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A shock wave passing through a gas and reflecting from a wall at a right angle to its path suddenly exposes the wall to a hot quiescent body of gas. The initial temperature rise of the wall surface is a function of temperature T, thermal conductivity k, density, and heat capacities of the gas and the solid. Smiley[1] combined equations of one-dimensional heat flow by conduction at constant pressure and the equation of continuity to analyze experimental data obtained with shock-heated argon at a Pyrex end wall. He reported k's for argon from 1000° to 3000° K. Hansen[2] used an analysis based on one-dimensional heat flow by conduction combined with consideration of chemical reactions to interpret data obtained in a similar experiment with air. The results were reported as integrals of k. Thomson[3] worked the equation of continuity into Hansen's analyses to include consideration of the heat transported by the movement of gas toward the cool wall. He used estimated values of k to calculate the initial temperature rise of the wall surface for various shocked gas temperatures. The experimental data for air agreed somewhat better with his analysis.

This note is a result of a recent experimental shock-tube study of thermal conductivities of gases. A thin-film platinum-on-Pyrex resistance thermometer was mounted normal to the shock travel in the center of a shock tube of 3- by 3-in. cross section. The distance from the diaphragm

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to the thermometer was 18 ft, 9 in. Based on shock speed, reflected shock temperatures of 665° to 8580° K were obtained in argon by using a helium driver. A typical thermometer output record is shown in Fig. 1.

The calculation of the k of argon from the data by the method of Smiley was unsatisfactory because of the uncertainty of the results at temperatures higher than about 3000° K.

As another approach, values of k were assumed[4] and the relation between the surface temperature rise and hot gas temperatures was calculated by the methods of Smiley, Hansen, and Thomson. The results are compared with experimental data in Fig. 2. The Smiley and Thomson analyses give the same results, and these agree with the experimental data better than the Hansen predictions. The Smiley and Thomson analyses were also made with $k = 0.379\times10^{-5}\, T^{3/2}/(167 + T)$, (cal)(cm^{-1})(sec^{-1})(°K^{-1}),[5] which gives values of k that are about the same as those of Amdur to 1000° K, but 24 percent lower at 5000° K, and 36 percent lower at 10,000° K. As shown in Fig. 2, the predicted temperature rise is decreased by only about 2 percent at 5000° K and 5 percent at 10,000° K. In other words, an error of 0.2° K in the temperature rise (at 1 atm) or of 100° K in the reflected shock temperature at 5000° K is equivalent to a change in k of about 20 percent.

In conclusion, the experimental data are in general agreement with those predicted by analyses developed by Smiley and Thomson. The data thus far obtained do not have the precision necessary to distinguish between theoretical k's that differ by only a few percent. They do indicate that, to about 8600° K, the generally accepted values for argon are approximately correct.

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Footnotes

1. E. F. Smiley, "The Measurement of the Thermal Conductivity of Gases at High Temperatures with a Shocktube; Experimental Results in Argon at Temperatures Between 1000° and 3000° K." (Ph.D. Thesis, The Catholic University of America, 1957).
2. C. F. Hansen, R. A. Early, F. E. Alzofon, and F. C. Witteborn, "Theoretical and Experimental Investigation of Heat Conduction in Air, Including Effects of Oxygen Dissociation." NASA TR R-27 (1959).
3. T. A. Thomson, "Heat Transport to a Solid Wall from a Suddenly Heated Gas." Australian Defense Scientific Service, Aero. Res. Labs., Aerodynamics Note 186 (Nov. 1960).
4. I. Amdur, and E. A. Mason, "Properties of Gases at Extremely High Temperatures." ASTIA AD No. 200968 (Aug. 1, 1958).
5. J. Hilsenrath, and Y. S. Touloukian, Trans. ASME 76, 967 (1954).

Figure Captions

Fig. 1. - Thin-film thermometer response in argon at $M_s = 3.74$ and $p_1 = 50$ Torr.

Fig. 2. - Pyrex surface temperature rise in shock-heated argon. O, experimental data; curve a, Smiley and Thomson analyses, Amdur k; curve b, Smiley and Thomson analyses, Hilsenrath k; curve c, Hansen analysis, Amdur k.

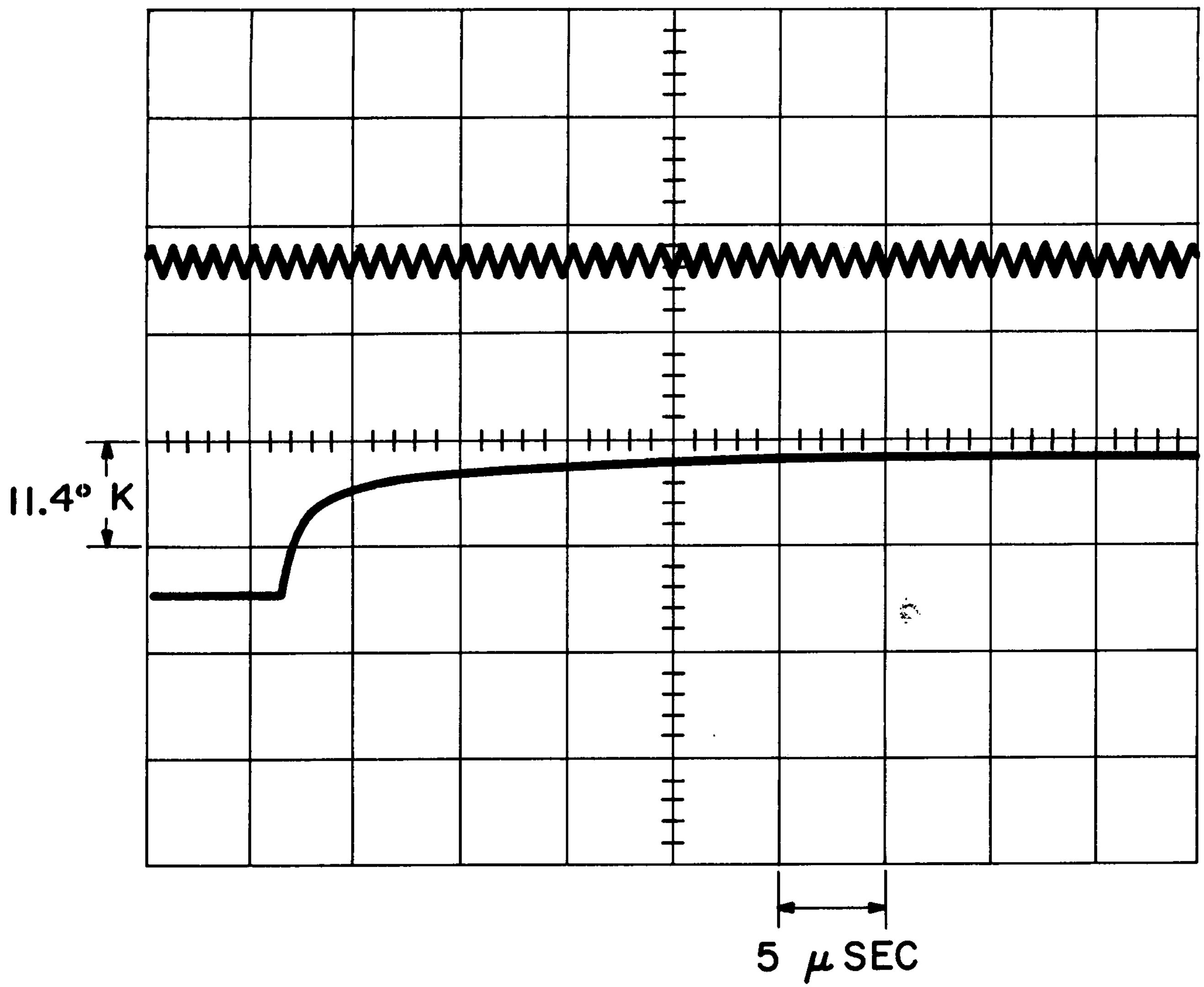

Fig. 1. - Thin-film thermometer response in argon at $M_3 = 3.74$ and $p_1 = 50$ torr.

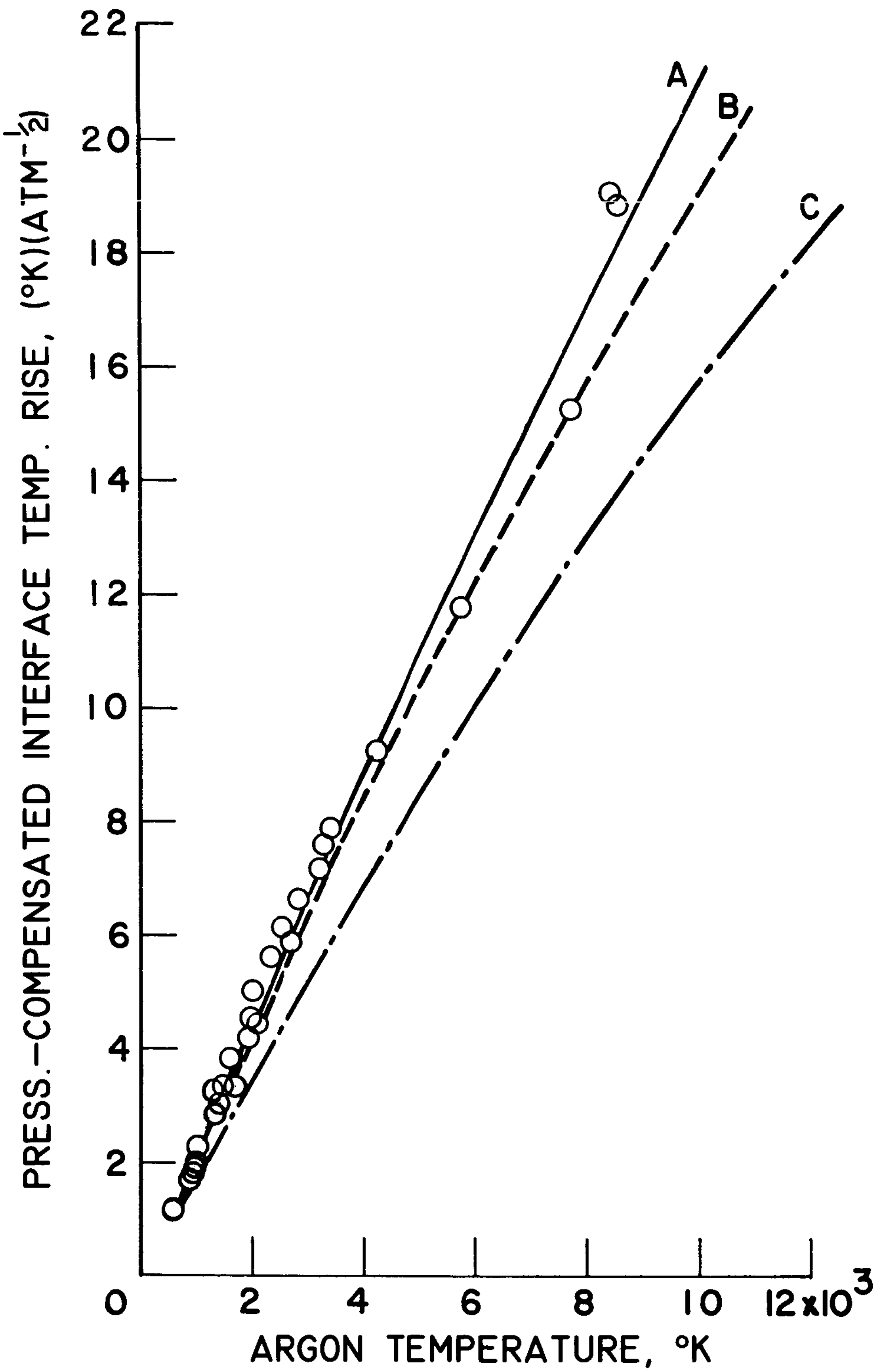

Fig. 2. - Pyrex surface temperature rise in shock-heated argon. O, experimental data; curve A, Smiley and Thomson analysis, Amdur k; curve B, Smiley and Thomson analysis, Hilsenrath k; curve C, Hansen analysis, Amdur k.